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Sinchrotron Studies of Single Crystal Lead Magnesium Niobate Under Applied Electric Field

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Introduction: Lead $PbMg_{1/3}Nb_{2/3}O_3$ (PMN) is a ferroelectric relaxor material attractive to capacitor and actuator industries, however better understanding of the microstructure is still needed for successful applications. Polar nano-regions of the rhombohedral phase were suggested to be responsible for observed relaxor behavior and glass-like properties at low temperatures. In this work we take advantage of the high resolution synchrotron radiation to study the effects of the electric field on the formation of the rhombohedral phase to complement similar studies of PMN using conventional rotating anode x-ray sources [1,2].

Methods and Materials: A single crystal of PMN with a surface normal perpendicular to (111) planes was grown by the Bridgman technique [3]. The crystal had the linear dimensions 5x7x0.5 mm^3. Dielectric measurements have confirmed relaxor behavior. Gold electrodes were deposited for in situ applications of the DC electric fields up to 6 kV/cm. Low temperature measurements were performed in closed cycle He compressed cryostat mounted on the four circle Huber diffractometer. The x-ray energy was tuned to 10 keV with double-crystal Si 111 monochromator and subsequently focused by cylindrical Si mirror on the sample. The beam size at the sample position was about 1 mm. The diffracted intensity was collected by the solid state Si detector.

Results: Fig. 1 shows the diffraction profile of 222 reflection taken after field cooling from room temperature to 150 K under 4 kV/cm applied electric field. We did not find any evidence of observed cubic to rhombohedral phase transition reported in previous studies [1,2]. Although the crystal shows relaxor behavior reported for PMN, the average size of the Nb/Mg ordered regions in this sample was estimated to be 25 Å compared to 50 Å in the materials which demonstrated the transition. It is known that the PMN and related material's properties are strongly dependent on the composition, degree of disorder and the method of preparation of the sample. Further work is needed to determine the significance of the induced rhombohedral phase transition for the relaxor behavior.

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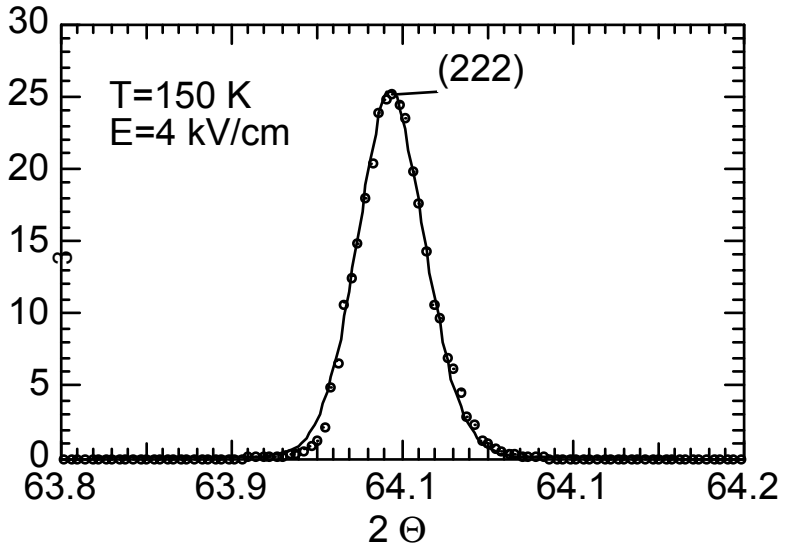

Figure 1. Intensity profile of (222) reflection after field cooling from 300 K to 150 K under 4 kV/cm electric field.